



Maine Department of  
Transportation  
**Transportation Research  
Division**



**Technical Report 03-2 & Third Year Interim  
Report**

*Experimental Placement of Stone Matrix Asphalt (SMA)  
Project F-STP-017P(89)E Auburn, Court Street*

*April 2003*

# Transportation Research Division

## *Experimental Placement of Stone Matrix Asphalt*

### **Introduction**

In October 1999 the Maine Department of Transportation utilized stone matrix asphalt to resurface an intersection in Auburn, Maine. The experimental placement of SMA was part of a pavement project F-STP-017P(89)E. The intersection is at the junction of Route 4 and Route 126 in Auburn, and is locally known as the intersection of Court Street and Minot Avenue/Union Street Bypass. The pre-existing pavement was severely rutted and had been subject to several overlay treatments in previous years. Due to the large amount of truck traffic at this intersection the decision was made to install a 12.5 mm nominal aggregate SMA to provide greater stability.

### **Construction Procedure**

The existing pavement was milled to a depth of about four inches, then two lifts of SMA were placed on this milled surface. The photographs in the following section show the construction process and the current status of the intersection. SMA was placed from station 154+20 to 202+50. The SMA on Minot Avenue and Union Street extended approximately the same distances from the intersection. The project required placing approximately 1,107 tons of 12.5 mm nominal SMA in two separate lifts. This placement was covered by contract special provision Section 404 (See Appendix 2).

Bituminous core density tests were performed on four cores. The results of the first lift were 96.1% and 96.6%. The results for the second lift were 93.1% and 93.3%.

Three samples were taken for further testing in the MDOT lab for asphalt content, volumetric analysis and gradation. The table below summarizes the test results.

Sample	1	2	3
Asphalt Content (%)	7.20	7.23	7.57
Air Voids (%)	2.1	2.4	2.3
Voids filled with Binder (%)	89.5	84.4	85.1

After it was rolled, the first lift appeared to have white blotches scattered throughout. These blotches turned out to be mineral filler. The filler was changed in subsequent batches, and this corrected the problem.

## Construction Photos



Figure 1. Constructing a Pad at beginning of SMA Section.



Figure 2. Paving Begins



Figure 3. White Blotches Appear (Mineral Filler) in the 1<sup>st</sup> Lift.



Figure 4. Close up of Blotches caused by Mineral Filler.



Figure 5.



Figure 6 Second Lift of SMA.

**Current Photos ( 3 Years after construction)**



Figure 7. Wheel paths are apparent.



Figure 8.



Figure 9.



Figure 10.



Figure 11.



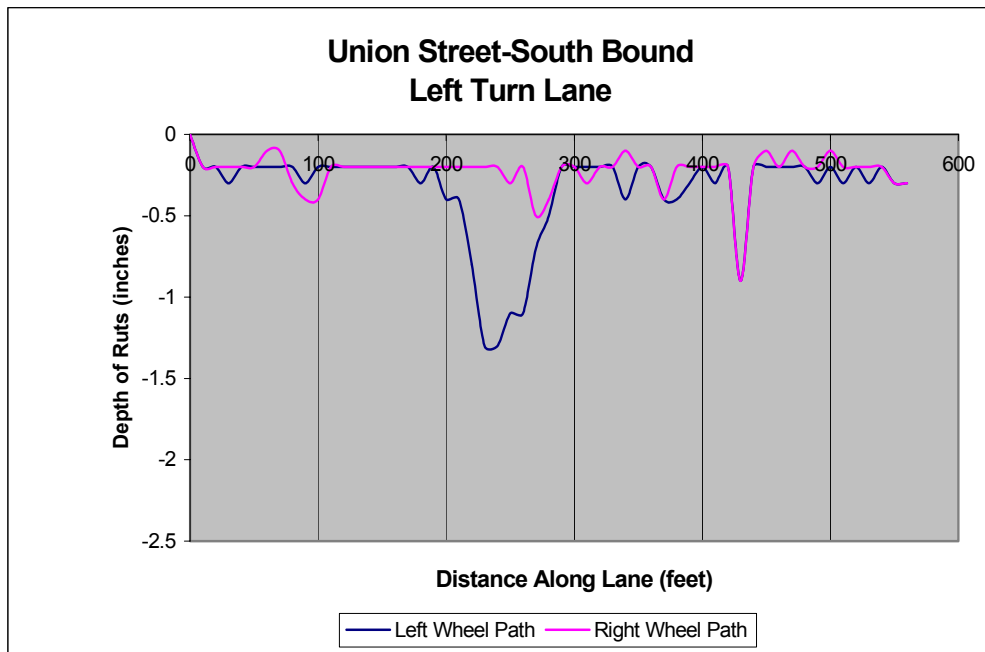
Figure 12.



Figure 13.

## Pavement Performance

During the three years since the project was constructed, some wheel path rutting has developed in certain areas of the intersection. Rut depths were measured using the Department's Automatic Road Analyzer (ARAN). Overall average rutting is less than 0.5 inch, however, localized 1 to 2 inch deep ruts have developed. The following table shows the rut depths for each lane. The deepest rutting has occurred in the left turn lanes and left hand turn lanes.



The charts in Appendix 1 show the rut depths in each lane in the direction of travel in feet, beginning at the start of the SMA treated section, and proceeding through each lane of the intersection. The data shown isn't a true continuous profile of the wheel path since they are based on readings taken every 10 feet. The worst rutting has occurred on the left turn lane on Minot Avenue northbound; the next worst is the left turn lane Union Street Bypass. The left-hand through lane on both on these legs also have almost 1 inch ruts. The left turn lanes on the opposing legs also have the worst rutting on those legs, however it is only half as bad as the north-south Minot Ave. and Union St. Bypass legs. This probably indicates the lanes most heavily used by trucks.

## Conclusions & Recommendation

Based on the test results it may be that the asphalt content was too high for this application. The percent of voids filled with binder (VFB) is therefore somewhat high. This could lead to premature rutting under heavy truck traffic. Further testing is needed to determine if the underlying HMA layer and subgrade layer are also contributing to the rutting. Future testing will involve taking cores and testing in the laboratory for rutting potential. The information developed from this testing will aid in the design of future applications of SMA. It is apparent, however, that in the future, particular attention needs to be given to mix design. In addition, special attention should be given to quality control to ensure strict adherence to

asphalt content and construction placement. It is recommended that future SMA pavements include rutting potential testing (Asphalt Pavement Analysis) as part of the mix design process.

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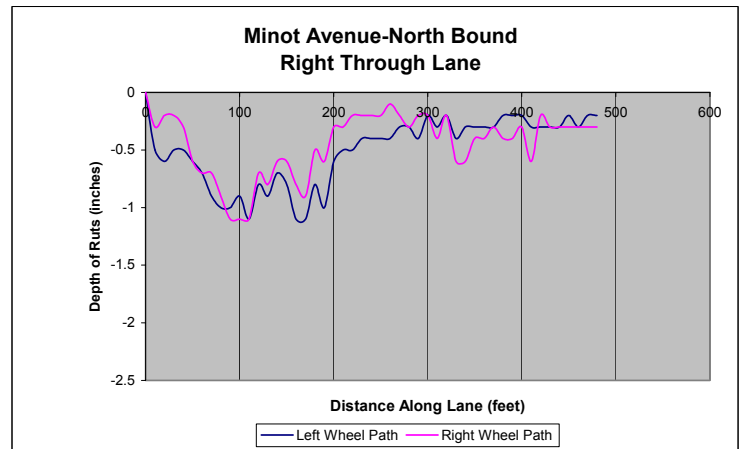
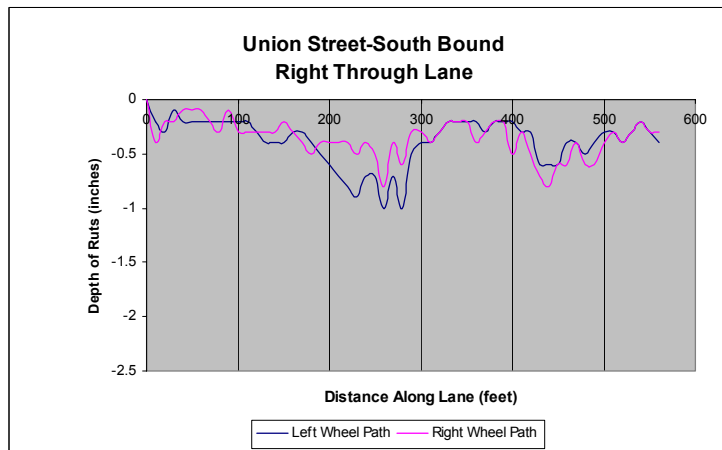
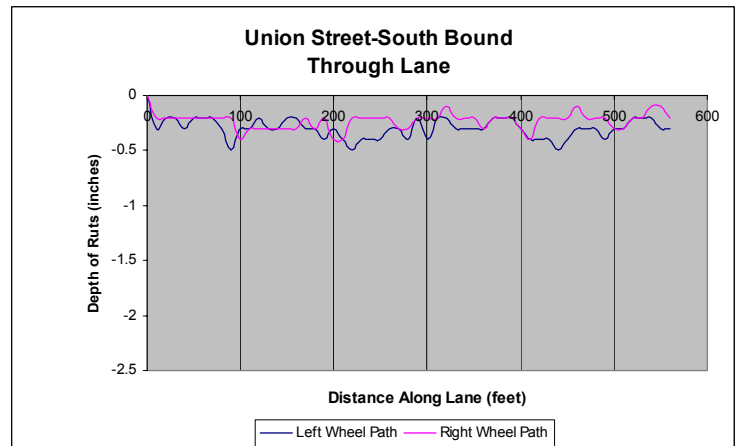
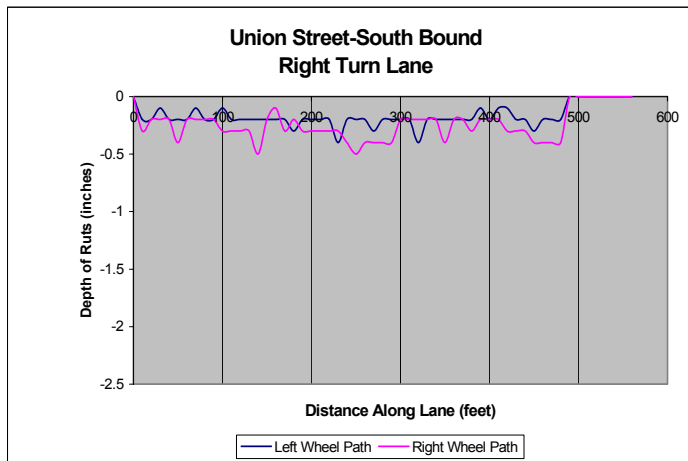
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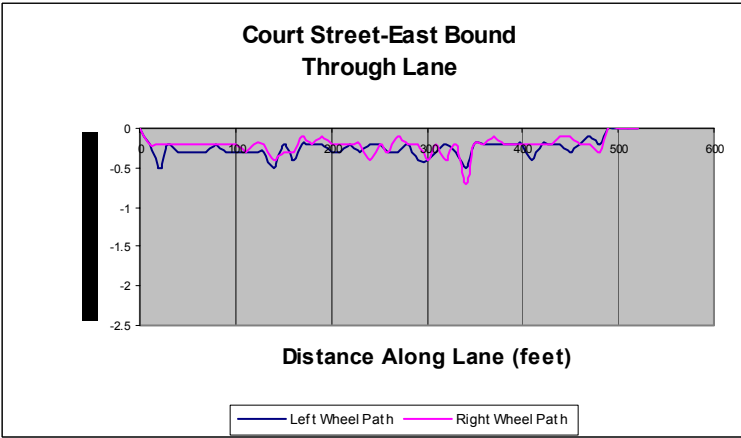
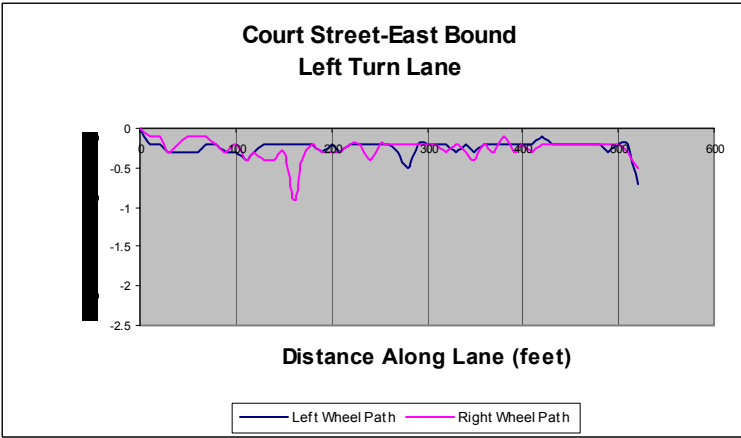
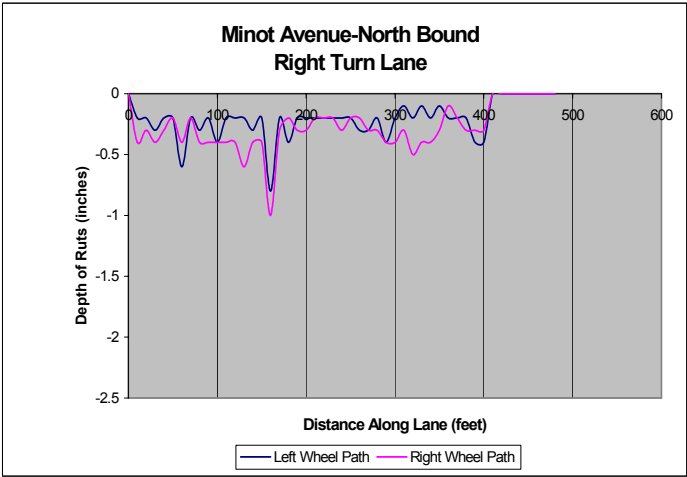
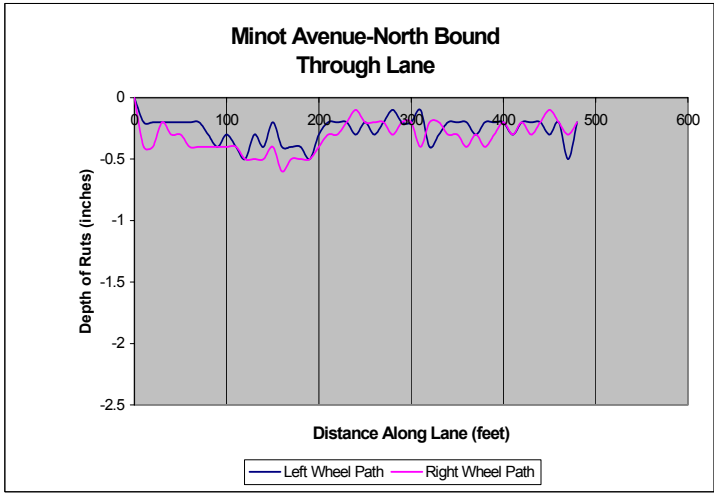
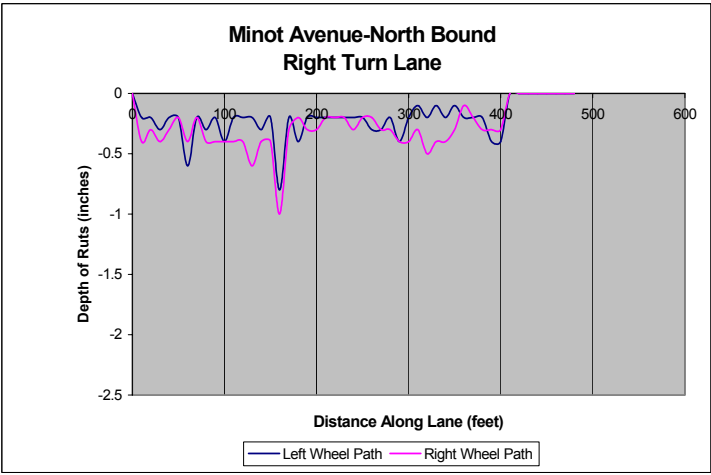
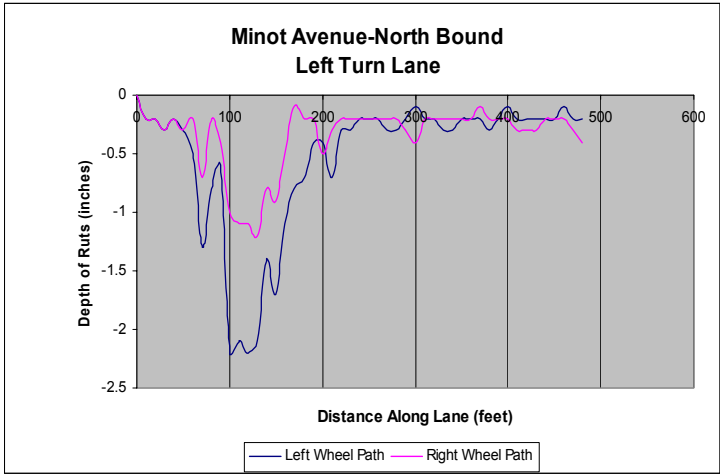
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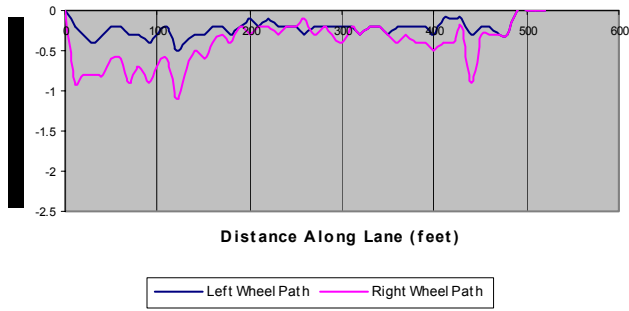
Photos- Wade McClay, Karen Gross  
Specifications- Brian Luce

## Appendix 1. Rut Depths in Each Lane





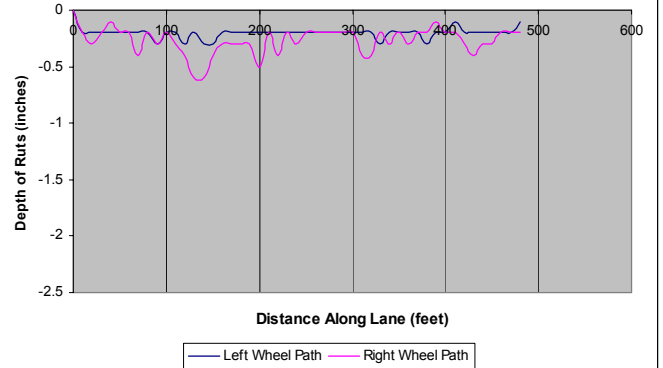
### Court Street-East Bound Right Turn Lane



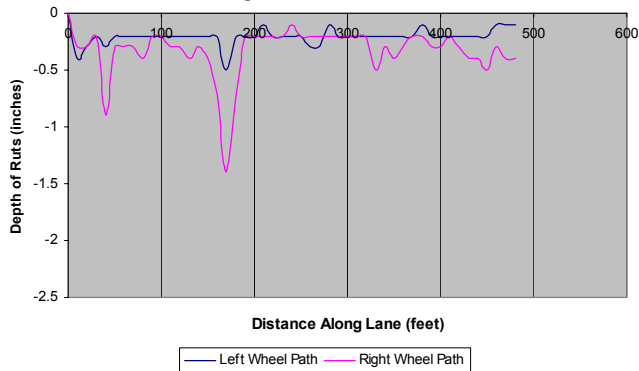
### Court Street-West Bound Left Turn Lane



### Court Street-West Bound Through Lane



### Court Street-West Bound Right Turn Lane



## Appendix 2.

### **SPECIAL PROVISION SECTION 404 STONE MATRIX ASPHALT**

#### **404.01 DESCRIPTION**

This work shall consist of constructing a surface course of fiber stabilized Stone Matrix Asphalt pavement over an existing, properly prepared pavement in accordance with these specifications and in reasonably close conformity with the lines, grades, thicknesses, and typical cross sections shown on the established plans.

#### **404.02 COMPOSITION OF THE SMA MIXTURE (JOB-MIX FORMULA)**

The asphalt mixture shall be composed of aggregate(s), mineral filler and asphalt cement, plus required additives and shall be combined as necessary to meet the project requirements.

It is the Contractor's responsibility to ensure that, in addition to the aggregate gradation requirements, the produced material will provide an asphalt mixture that conforms to the applicable design parameters listed in Table 1-1.

The Contractor shall submit in writing to the Engineer, at least 15 calendar days prior to production, the proposed job-mix formula (J7MF) For approval including the following:

- (a) The percentage (in units of one percent) of aggregate passing each specified sieve, (except the .0075 n-un (No. 200sieve)), based on the total dry weight of aggregate as determined by AASHTO T-11 and T-27.
- (b) The percentage (in units of one-tenth of one percent) of aggregate passing the 0.0075 mm (No. 200) sieve, based on the dry weight of aggregate as determined by AASHTO T-11.
- (c) The percentage (In units of one-tenth of one percent) of aggregate finer than 0.020 mm in size, based on the dry weight of aggregate as determined by AASHTO T-88.
- (d) The percentage (in units of one-tenth of one percent) of asphalt material to be added, based upon the total weight of the mixture.
- (e) The proposed percentage of each stockpile to be used, the average gradation of each stockpile, and the proposed target value for each sieve size. The target values and the combined average gradation of all the stockpiles when combined in accordance with the Contractor's recommended stockpile combinations shall be within the gradation ranges for the designated grading in Table 1-2.
- (f) The type and amount by weight of mix of stabilizer additive to be used.
- (g) Additional information required as part of the JM7F shall include the following:
  - (1) The material sources for all ingredients.

**The Following properties will be determined by MDOT:**

- (2) The material properties, as listed, for all ingredients:

The specific gravities of the individual aggregates and asphalt.

The L. A. Abrasion of the aggregates.

The Sand Equivalent value of the combined aggregate.

The Flat and elongated percent of the coarse aggregate (3 to 1 and 5 to 1 ratios) retained above the 4.75 mm (No. 4) sieve.

The Plastic Index of the aggregate.

The absorption of the aggregates.

The asphalt temperature/viscosity curves.

- (3) The mixing temperature.

- (4) The mix design test property and curves used to develop the job mix in accordance with the Asphalt Institute's Manual Series No. 2 (MS-2).

- (5) The plot of the gradation on the FHWA 0.45 power gradation chart.

**Table 1-1**

**SMA MIX REQUIREMENTS**

Design Parameters

Design Parameters		
VTM, percent <sup>1</sup>		3-4
Asphalt Content, percent <sup>2</sup>		6.0
VMA <sup>3</sup>	Mm.	
Draindown, percent <sup>4</sup>		17
Gyrations <sup>5</sup>	Mm.	
		0.3
	max. (1 hour reading)	
		100
	Revolutions	

<sup>1</sup> VTM (Voids in Total Mix)

<sup>2</sup> Based on weight of total mix.

<sup>3</sup> VMA Voids in the Mineral Aggregate.

<sup>4</sup> NCAT SMA Asphalt Draindown Test

<sup>5</sup> Superpave Gyratory compactor @ 100 Revolutions (N<sub>d</sub>)

#### **404.03 AGGREGATE**

Coarse Aggregate. Coarse aggregate shall be crushed, non-absorptive stone and unless otherwise stipulated, shall conform to the following quality requirements of AASHTQ M 283 for class A aggregates:

- |   |           |
|---|-----------|
| (1) Los Angeles abrasion, AASHTO T 96   | 30% max.  |
| (2) Flat and Elongated Particles,<br>ASTM D 4791, comparing length to<br>thickness (Measured on material<br>retained above the 4.75 mm (No. 4) Sieve) |           |
| 3 to 1  | 20% max.  |
| 5 to 1  | 5% max    |
| (3) Washington State Degradation test of 1967<br>(As modified by MDOT JUNE 1993)  | 30 min.   |
| (4) Particles retained on the 4.75 mm (No. 4) sieve<br>shall have at least  |           |
| one fractured face,   | 100% min. |
| Two fractured faces   | 90% min.  |
| (5) Absorption, AASHTO T 85   | 2% max.   |
| (6) Durability index (AASHTO T 210)   |           |
| Coarse  | 40 Min.   |
| Fine  | 70 Min.   |

(b) Fine Aggregate. Fine aggregate shall consist of a blend of 100% crushed, manufactured sand. It shall conform to the following quality requirements. Durability index, 70 mm. The liquid limit shall not exceed 25 as determined by AASHTO T 89.

(c) The several aggregate fractions for the mixture shall be sized, graded and combined in such proportions that the resulting composite blend conforms to Table 1-2 for the grading shown in the bid schedule.

**Table 1-2**

**GRADATION TARGET VALUE RANGES FOR STONE MATRIX ASPHALT**  
(Percentage by Weight Passing Sieves, AASI-ITO T 27 & T 11)

Sieve Size	Percent Passing
19.0mm (3/4 in)	100%
12.5 mm (1/2 in)	85-95
9.5 mm (3.8 in)	75 maximum
4.75 mm (No. 4)	20-28
2.36mm(No. 8)	16-24
0.60mm(No. 30)	12-16
0.30mm(No. 50)	12-15
0.075 mm (No. 200)	8-10
0.020mm	Less than 3*

\* To be controlled from a combination of aggregate and mineral filler taken from representative stockpile samples.

**404.06 ASPHALT CEMENT**

(a) Asphalt cement shall conform to AASHTO M 226, table 2. It shall be AC-20 or its approved PG equivalent.

(b) Asphalt cement shall be mixed at a temperature as required to achieve a viscosity of 170 +1-20 centistokes. Typical plant mixing temperature for SMA is 155°~ 163 °C (310 °~325 °F). However, at no time shall the mixing temperature exceed 177 °C (350 °F).

**404.06 1 MINERAL FILLER**

(a) Mineral filler shall consist of finely divided mineral matter such as rock or limestone dust of other suitable material. At the time of use it shall be sufficiently dry to flow freely and essentially free from agglomerations. Filler shall be free from organic impurities and have a plasticity index not greater than 4. Filler material for the mix shall meet the requirements of AASHTO M 17.

(b) Commercial mineral filler added to the SMA mixture, shall be limited to less than 20% of its weight smaller in size than .020 mm.

**404.062 STABILIZER ADDITIVE**

A fiber stabilizer, either cellulose or mineral fiber is to be utilized. Dosage rates for cellulose 0.3% by weight of the total mix, and for mineral fiber is 0.4% by weight of the total mix. Allowable tolerances of fiber dosage shall be +1- 10% of the required fiber weight. The selected fiber shall meet the properties described in Table 1-3 or 1-4 utilizing the listed test procedures.

**Table 1-3**

**CELLULOSE FIBER PROPERTIES**

Cellulose Fibers

Sieve Analysis  
Alpine Sieve' Analysis:

Fiber Length	6 mm (0.25") (maximum)
Passing 0.150 mm (No. 100) Sieve	70% ( $\pm 1-10\%$ )
Ash Content <sup>2</sup>	18% (+1-5%) non-volatiles
pH <sup>3</sup>	7.5 $\pm$ 1
Oil Absorption <sup>4</sup>	5.0 (+1-1.0) Times Fiber Weight
Moisture Content <sup>5</sup>	<5% by weight

<sup>1</sup> **Alpine Sieve Analysis.** This test is performed using an Alpine Air Jet Sieve (Type 200 LS). A representative five gram sample of fiber is sieved for 14 minutes at a controlled vacuum of 75 kPa (11 psi). The portion remaining on the screen is weighed.

<sup>2</sup> **Ash Content.** A representative 2-3 gram sample of fiber is placed in a tared crucible and heated between 595° and 650° C (1100° and 1200°F) for not less than two hours. The crucible and ash are cooled in a desiccator and reweighed.

<sup>3</sup> **pH Test.** Five grams of fiber is added to 100 ml of distilled water, stirred and let sit for 30 minutes. The pH is determined with a probe calibrated with pH 7.0 buffer.

<sup>4</sup> **Oil Absorption Test.** Five grams of fiber is accurately weighed and suspended in an excess of mineral spirits for not less than five minutes to ensure total saturation. It is then placed in a screen mesh strainer (approximately 0.5 square millimeter hole size) and shaken on a wrist action shaker for ten minutes (approximately 1 - ¼ inch motion at 240 shakes/minute). The shaken mass is then transferred without touching, to a tared

container and weighed. Results are reported as the amount (number of times it's own weight) the fibers are able to absorb.

<sup>5</sup> **Moisture Content.** Then grams of fiber is weighed and placed in a 121 °C (250 °F) forced air oven for two hours. The sample is then reweighed immediately upon removal from the oven.

**Table 1-4**

### MINERAL FIBER PROPERTIES

#### Mineral fibers<sup>1</sup>

Size Analysis	
Fiber Length <sup>2</sup>	6 mm (.25") maximum mean test value
Thickness <sup>3</sup>	.050 mm (0.0002") maximum mean test value
Shot Content <sup>4</sup>	
0.250 mm (No. 60) Sieve	95% passing (minimum)
0.063 mm (No. 230) Sieve	65% passing (minimum)

<sup>1</sup> The European experience and development of the above criteria are based on the use of basalt mineral fibers.

<sup>2</sup> The fiber length is determined according to the Bauer McNett fractionation.

<sup>3</sup> The fiber diameter is determined by measuring at least 200 fibers in a phase contrast microscope.

<sup>4</sup> Shot content is a measure of non-fibrous material. The shot content is determined on vibrating sieves. Two sieves, No. 60 and No. 230 are typically utilized, for additional information see ASTM C612.

**404.07 Weather and Seasonal Limitations.** The SMA mixture shall be placed on a clean, dry, unfrozen Surface when the atmospheric temperature in the shade and of the roadbed is above 10 oC (50 oF) and rising and the mix conforms to the applicable requirements shown under Placing and Finishing (404.16).

**404.071 Conditioning of Existing Surface.**

- (a) Immediately before placing the SMA mixture, the existing surface shall be cleaned of all loose or deleterious material by brooming or other approved means.
- (b) A thin tack coat of asphalt emulsion (HFMS- 1 or similar material) conforming to AASHTO M 140 or M208 shall be applied to ensure uniform and complete adherence of the overlay. The asphalt emulsion used for this purpose will be diluted with an equal part of water and the diluted emulsion be applied at between 0.05 and 0.1 gal/square yard.
- (c) When the existing surface is distorted, a leveling course of Hot Mix Asphalt shall be required to restore proper cross-section prior to construction of the overlay.

**404.072 Control of Asphalt Mixture.**

The SMA mixture furnished by the Contractor shall conform to the job-mix formula, within the allowable deviations from the target values. The allowable deviations from the target values for the JMF of the aggregate shall be  $\pm 1 - 4\%$  for the 19.0 mm (3/4"), 12.5 mm (1/2"), and 9.5 mm (3/8") sieve,  $\pm 1 - 3\%$  for the 4.75 mm (No. 4), 2.36 mm (No. 8), 0.60 mm (No. 30) and .300 mm (No. 50) sieve, and  $\pm 1 - 2\%$  for the 0.075 mm (No. 200) sieve. The allowable deviation for the asphalt content shall be  $\pm 1 - 0.3\%$ .

**404.08 Bituminous Mixing Plant.**

**404.08 1 General Requirements.** Mixing plants shall conform to AASHTQ M 156. An efficient dust collecting system shall be provided to prevent the loss of fine material. The material collected may be returned to the mixture at a uniform rate or discarded.

Prior to placing of any mix, a Pre-paving conference shall be held to discuss and approve the paving schedule, source of mix, type and amount of equipment to be used, sequence of paving pattern, rate of mix supply, and traffic control. All field and plant supervisors shall attend this meeting.

- (a) Truck Scales. When the bituminous mixture is weighed on scales meeting the requirements of Section 109 -- Measurement and Payment. The scales shall be inspected and sealed by the State Sealer as often as the Engineer deems necessary to assure their accuracy.
- (b) Safety Requirements. Adequate and safe stairways to the mixing platform and sampling points shall be provided and guarded ladders to other plant units shall be placed at points where accessibility to plant operations is required. Accessibility to the top of truck bodies shall be provided by a platform or other suitable device placed in an acceptable

location near the testing laboratory to enable the Engineer to obtain samples and mix temperature data.

Ample and unobstructed space shall be provided on the mixing platform. A clear and unobstructed passage shall be maintained at all times in and around the truck loading area. This area shall be kept free of drippings from the mixing platform.

All gears, pulleys, chains, sprockets and other dangerous moving parts shall be thoroughly guarded and protected.

**404.082 Vacant.**

**404.083 Automation of Batching.** Standard Specifications (401 .083) shall apply.

**404.084 Vacant.**

**404.085 Drum Plant Recordation of Proportions.** Standard Specifications (401 .085) shall apply.

**404.09 Hauling Equipment.** Trucks for hauling bituminous mixtures shall have tight, clean, smooth metal bodies which have been thinly coated with a small amount of lime solution or an approved soap solution or detergent to prevent the mixture from adhering to the bodies.

All trucks shall have a cover of canvas or other water repellent material capable of heat retention and of such size to completely cover the mixture. The cover shall be securely fastened on the loaded truck at all times except when unloading.

All truck bodies shall have an opening on both sides which will accommodate a thermometer stem. The opening shall be located at the midpoint of the body, at least one foot above the bed.

**404.10 Bituminous Payers.** Bituminous payers shall be self-contained, self-propelled units, equipped with an activated screed, heated if necessary and capable of spreading and finishing courses of bituminous plant mix material in lane widths to the specified typical section and thickness' shown on the plans. Payers used for shoulders and similar construction shall be capable of spreading and finishing~ courses of bituminous plant mix material in widths shown on the plans.

The bituminous mixtures placed on the main line shall be placed by a paver equipped with an automatic grade and slope controlled screed, unless otherwise directed by the Engineer. The controls shall automatically adjust the screed and increase or decrease the layer thickness to compensate for irregularities in the preceding course. The controls shall be capable of maintaining the proper transverse slope and be readily adjustable so that transitions and superelevated curves can be properly paved. The controls shall be operated from a fixed or moving reference such as a grade wire or ski type device (floating beam) with a minimum length of 30 ft. A 40 ft. ski shall be required on Interstate projects.

Pavers with extendible screeds shall have auger extensions and tunnel extenders as necessary.

The paver shall have a receiving hopper with sufficient capacity for a uniform spreading operation and a distribution system to place the mixture uniformly and without segregation in front of the screed.

The screed assembly shall produce a finished surface of the required evenness and texture without tearing, shoving or gouging the mixture.

The paver shall be operated, at speeds that produce a uniform mat.

Bituminous pavers shall be at the project site sufficiently ahead of the start of paving operations to be inspected and approved. Any paver found worn or defective either before or during its use shall be replaced or repaired to the satisfaction of the Engineer.

**404.11 Rollers.** Rollers shall be either static steel, or pneumatic tire or approved vibrator type. Rollers shall be in good mechanical condition, capable of starting and stopping smoothly without jerking and also be free from backlash when reversing direction. They shall be equipped and operated in such a way as to prevent the picking up of hot mixed material by the tires or roller surface. Use of rollers which result in crushing of the aggregate or displacement of the mixture will not be permitted. Any asphalt pavement that becomes loose, broken, contaminated, shows an excess or deficiency of asphalt cement, or is in any way defective, shall be removed and replaced at no additional cost with fresh hot asphalt mix which shall be immediately compacted to conform with the surrounding area.

The type of rollers to be used and their relative position in the compaction sequence shall generally be the Contractor's option, provided specification densities are attained and with the following stipulations:

- 1) Vibratory rollers shall not be operated in the vibratory mode under the following conditions; when checking or cracking of the mat occurs and on bridge decks.
- 2) Any method which results in cracking or checking of the mat will be discontinued, and corrective action taken.
- 3) Pneumatic tired rollers may be used after the mix cools to improve density and/or texture as directed by the construction manager.

The maximum operating speed for a steel wheel roller shall not exceed the manufacturer's recommendations.

**404.111 and 404.112** Vacant

**404.12 through 404.14.** Standard Specifications 401.12 through 401.14 shall apply.

**404.15 Mixing.**

The dried aggregate shall be combined in the mixer in the amount of each fraction of aggregate required to meet the job mix formula. The bituminous material shall be measured or gauged and introduced into the mixer in the amount specified by the job mix formula.

For hot bituminous pavement the mixture shall be produced at the temperature established by the job-mix formula.

The aggregate shall be sufficiently dried so that the mixture will not flush, foam excessively or displace excessively under the action of the rollers. It shall be introduced into the mixer at a temperature of not more than 14<sup>0</sup>C above the temperature at which the viscosity of the bituminous material being used is 150 centistokes.

The bituminous material shall be stored and introduced into the mixer at a uniformly maintained temperature which shall be within the limits at which the viscosity of the material is between 150 and 300 centistokes.

The material shall have a complete and uniform coating of the particles and a thorough distribution of the bituminous material throughout the aggregate. Wet mixing time will be determined by the Contractor and approved by the Engineer for each plant

and for each type of aggregate used.

#### **404.16 Placing and Finishing.**

On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impracticable, the mixture shall be spread, raked and luted with hand tools. For such areas the mixture shall be dumped, spread and screeded to give the required compacted thickness.

When production of the mixture can be maintained and when practical, pavers shall be used in echelon to place the course in adjacent lanes.

On roads opened to two way traffic, the placement of each course shall be completed over the full width of the traveled way section being paved on each days run unless otherwise approved.

The mixture, when delivered to the paver, shall have a temperature of not less than 143 oC (290 oF). The mixture temperature shall be measured in the truck just prior to dumping into the spreader.

Placing speed will be adjusted so that sufficient time is allowed for compaction operations and to provide continuity.

**Table 1-5: GRADATION AND ASPHALT CEMENT ACCEPTANCE LIMITS**

<b>Property</b>	<b>USL and LSL</b>
Passing 9.5 mm and larger sieves	Target + 4 percent
Passing 0.3 00 mm to 4.75 mm sieves	Target + 4 percent
Passing 0.0275 mm	Target ± 3 percent
Asphalt cement	Target ± 0.3 percent
Air Voids (Target 4%)	Target + 1.0 percent

#### **404.17 Compaction.**

Immediately after the bituminous mixture has been spread, struck off and surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling.

Due to the nature of SMA mixture the surface shall be rolled immediately. Rolling shall be accomplished with steel wheel rollers of a minimum weight of 9 MG (10 Tons) Pneumatic tire rollers shall not be used on SMA except as allowed in section 404.11. Rolling procedures should be adjusted to provide the specified pavement density. Rollers shall move at a uniform speed not to exceed 5 KPH (3 mph) with the drive roller nearest the paver. Rolling shall be continued until all the roller marks are eliminated and the minimum density has been obtained but not after the mat has cooled to 116 °C (240 °F) or lower. The Contractor shall monitor density during the compaction process by use of nuclear density gauges to assure that the minimum required compaction is being obtained.

Any displacement occurring as a result of the reversing of the direction of a roller or from other causes, shall be corrected at once to the satisfaction of the Engineer.

Along forms, curbs, headers, walls, and other places not accessible to the rollers, the mixture shall be thoroughly compacted with mechanical vibrating compactors. Hand tamping will be permitted only for areas inaccessible to other compaction

equipment. On depressed areas, a trench roller may be used or cleated compression strips may be used under the roller to transmit compression to the depressed area.

Mixture that becomes loose and broken, mixed with dirt or is in any way defective shall be removed and replaced at no additional cost with fresh, hot mixture, which shall be compacted to conform with the surrounding area. Mixture showing an excess or deficiency of bituminous material shall be removed and replaced at no additional cost.

To prevent adhesion of the mixture to the rollers, it shall be necessary to keep the wheels properly moistened with water mixed with very small quantities of detergent or other approved material.

The pavement shall be compacted to at least 94% of maximum theoretical density.

Once sufficient in-place density has been achieved, rolling operations should cease, as over rolling may cause migration of asphalt cement and filler to the compacted pavement surface.

Traffic shall not be placed on the newly compacted surface, until the mat has cooled to 60 °C (140 °F) or lower.

**404.18 Joints.** Standard Specifications shall apply.

**404.19 Pavement Samples.**

Except as hereafter provided, pavement density measurements will be performed by the State on the compacted wearing surfaces using a nuclear density gauge. A control section of pavement approximately 150 m (500 feet) long will be designated at the start of the paving operations. Within the control section at least three randomly selected locations will be tested, to calibrate the nuclear density gauge.

After placement of pavement the Contractor shall cool the pavement to be tested by using ice and promptly cut the necessary calibration cores. After cooling to 20° C (70° F) the cores shall be removed from the road using an acceptable core removing tool to assure minimum damage to the core.

The nuclear density gauge will then be adjusted to reflect the average of the cores. The Engineer reserves the right to designate a new control section at any time.

Each day's placement will be divided into test sections one paver width wide for density testing.

The minimum acceptable density for each test section shall be as follows:

94% of theoretical maximum density (TMD)

When nuclear testing is required at locations outside normal paving and traffic control areas, the Contractor shall furnish a flagger and other necessary safety devices to protect personnel and equipment.

If the nuclear density gauge is not available the Contractor may be required to cut cores using the following procedure:

On the first day of paving and immediately after the initial pavement has cooled enough to obtain an undisturbed sample,

the Contractor shall cut sample cores from the compacted wearing surface for testing by the Engineer. Samples shall be taken for the full depth of the course. On the morning of the second and all subsequent working days the Contractor shall cut sample cores from the previous days placement and present them to the plant inspector prior to 10:00 A.M. All first and subsequent day sample locations will be as designated by the Engineer.

After compaction, the percentage of the TMD obtained shall be a minimum of 94 percent for all machine placed courses. The test for percentage of the TMD shall be performed in accordance with AASHTQ T209 on plant produced specimens of mixture combined in the same proportions as the job mix formula.

All holes in the pavement resulting from cutting cores by the Engineer or by the Contractor shall be filled with acceptable mixture no later than the following work day. Before filling, the holes shall be carefully cleaned and coated with emulsified asphalt.

**404.20 Surface tolerances.**

The surface shall be tested by the Engineer with a 4.9 m (16 foot) straightedge or string line placed parallel to the centerline of pavement and with a 3 m (10 foot) straightedge or string line placed transversely to the centerline of pavement. Variations exceeding 6 mm (1/4 inch) shall be corrected by removing defective work and replacing it with new material as directed. A 3 m (10 foot) straightedge, shall be furnished by the paving contractor.

**404.21 Method of Measurement.** Standard Specifications 401.21 shall apply.

**404.22 Basis of Payment.** Payment shall be made under Item 403.1